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THE NASA-LEWIS/ERDA SOLAR HEATING AND COOLING TECHNOLOGY PROGRAM

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ABSTRACT

The NASA Lewis Research Center plans to carry out a major role in the ERDA Solar Heating and Cooling Program. This role would be to create and test the enabling technology for future solar heating, cooling, and combined heating/cooling systems. The major objectives of the project are to achieve reduction in solar energy system costs, while maintaining adequate performance, reliability, life, and maintenance characteristics. The project approach is to move progressively through component, subsystem, and then system technology advancement phases in parallel with continuing manufacturing cost assessment studies. This approach will be accomplished principally by contract with industry to develop advanced components and subsystems. This advanced hardware will be tested to establish "technology readiness" both under controlled laboratory conditions and under real sun conditions.

INTRODUCTION

Although the use of the Sun's energy to provide heating and, to a lesser extent, cooling is not new, there are a number of constraints to its widespread utilization. The present status of solar utilization techniques is such that the three residential solar applications--water heating, space heating, and space cooling--differ substantially in degree of development. For example, the technology of solar water heaters is well developed and commercial units are available, but combined heating and cooling systems (which include water heating) are still under development. However, initial appraisal of costs shows that combined systems, with

their higher use factor on capital intensive equipment, may in many cases have a decided economic advantage over heating or cooling systems alone.

A joint NSF/NASA Solar Energy Panel recommended in 1972 that a 5-year national R&D effort be undertaken to develop solar heating and cooling because of its potentially significant impact on the Nation's energy picture. In the fall of 1973, a major energy study entitled "The Nation's Energy Future" (ref. 1) was submitted to the President by the Chairman of the Atomic Energy Commission. This report recommended and outlined a 5-year solar heating and cooling plan.

Designated by the Administration, prior to the formation of the Energy Research and Development Administration (ERDA), as the governmental lead agency in solar energy, the National Science Foundation (NSF) had formulated and begun to implement such a program. In the NSF budget submission to the Office of Management and Budget (OMB) in 1974, a $210 Million, 5-year program was outlined for solar heating and cooling. The initial effort on this program has included: (a) three major "phase zero" studies which have been completed (ref. 2): (b) several proof-of concept experiments which are being carried out in the public sector using existing technology (Generation I systems); and (c) grants and contracts which have been awarded to initiate an advanced research and technology (ART) program.

In addition to the foregoing, the NASA has under way a project to utilize solar energy to heat and cool a new office building now under construction at its Langley Research Center at Hampton, Virginia. This project will provide a "test bed" for solar collector and solar system evaluations under field conditions. The NASA-Lewis Research Center is providing the solar technology support for this project.

ERDA is currently working to define a new National Solar Heating and Cooling Research, Development and Demonstration Program (ref. 3) which incorporates appropriate elements of the several related activities previously assigned to NSF, NASA, the Department of Housing and Urban Development (HUD), AEC, the General Services Administration (GSA), and the National Bureau of Standards. The NASA-Lewis project is designed to provide the advanced research and technology required by the

evolving ERDA program. For this reason, the specifics of the project will be modified as necessary to accommodate specific changes which may be required to assure continuing support of the new National program.

Technical Plan

Goal: The goal of this project is to create, and by test to evaluate, the enabling technology for the Generation II solar heating, cooling, and combined heating/cooling systems. Generation II components and subsystems show significant technology advancement beyond today's Generation I components, and are more cost competetive with conventional heating and cooling systems.

Objectives: The major objectives of this project are (1) to achieve significant solar component technology advancement, (2) to incorporate these advanced components into system designs that are significantly lower in cost and higher in performance and reliability than present day Generation I systems, (3) to establish the technology readiness of these systems via breadboard tests, and (4) to create an in-place ability in industry, small and large, to produce these low-cost components and subsystems.

The specific technical objectives are: (1) to design, fabricate, and test two-to-four advanced solar heating or solar cooling systems within four years, (2) to design, fabricate, and test two-to-five advanced combined solar heating and cooling systems within five years, (3) to establish advanced component technology beyond that used in the final systems breadboard tests, and (4) to establish key low-cost manufacturing technology.

Approach: This project is based on an approach that moves successively through component, subsystems, and then system technology phases in parallel with continuing manufacturing cost assessment studies. Specifically, we will: (1) use and expand on the established solar experience, skills, and test facilities at NASA-Lewis, (2) establish many contracts with industry (small and large) to develop advanced components and subsystems and to perform cost assessment studies, (3) monitor selected

projects within the total ERDA program, and (4) set up a project office at the NASA-Lewis to achieve project objectives, to interface with the ERDA Program Manager, to coordinate with NASA-Marshall demonstration-related activities, and to draw on other center skills as appropriate.

A key element to success will lie in achieving significant reduction in system costs, while maintaining adequate performance, reliability, life, and maintenance characteristics. From the beginning of this project, low cost will be emphasized. All of the components, subsystems, and final breadboard systems investigated will be tested at NASA-Lewis, both under controlled laboratory conditions, and under real sun conditions. In addition, they will be tested under real sun conditions in at least two other significantly different geographic locations.

An overview of the project schedule, together with a listing of the major milestones is shown in figure 1.

Project Phasing: In the initial phase of the cost assessment studies, NASA, working with contractors knowledgeable in low-cost techniques, will evaluate materials and processes to provide guidelines for cost minimization. This activity, which will be completed by the first quarter of 1977, will result in a cost envelope for mass-produced components, with emphasis on collectors, using a variety of construction materials and manufacturing techniques.

The component technology phase will serve to analyze, design, fabricate, and test components to verify initial cost and performance estimates. Initial performance estimates of a large number of system configurations will be based on computer model systems analysis codes. An iteration loop between systems analysis and cost assessment will provide component performance/cost requirements and specifications. The design, fabrication and testing of selected components and controls will be accomplished by using a relatively large number of small contracts. After evaluation by NASA-Lewis is completed, components will be selected for assembly into subsystems. To insure project completion within schedule, this selection must take place no later than the first quarter of 1977. Advanced component technology activity will continue beyond this date to insure the continued development of new and innovative concepts for advanced systems

beyond those to be tested by the end of this project.

The subsystem technology phase is directed to testing and evaluating selected components assembled into subsystems. A typical subsystem for cooling would include a cooler (absorption, adsorption, dessicant, etc.), a low-temperature storage tank (sensible or latent heat materials), a heat exchanger (liquid to air), pumps, valves, piping, and associated instrumentation and controls.

The testing of subsystems will not only provide performance data, but will permit evaluation of component interfaces, hardware/installation, and test procedures. Modifications to these simple assemblies of components can be conveniently accomplished to provide trade-off and comparison data for a wide selection of prototypes. In addition, testing will evaluate final designs of applicable control systems developed earlier. In order to maintain project schedule, subsystem evaluations and selections must be complete by mid-1978. Sufficient time exists for further subsystem testing of advanced components to insure the continued development and evaluation of new and innovative systems.

The systems technology effort is a parallel activity that culminates in breadboard testing of full-scale selected Generation II systems. Many contractors with broad capabilities in heating/cooling and testing will be used. This project phase includes a 1-year testing period to permit reliability estimates of systems already selected on the basis of low cost and high performance.

A more detailed overview of the project showing flow and interaction of activities is given in figure 2. The critical flow path for project completion is indicated by heavy connecting lines. A more detailed yearly summary of project activities follows.

The initial phase, beginning in FY'76 will focus on component and subsystem advancements, early cost assessment guidelines, initial software definition for system analysis studies, new coatings investigations, and advanced collector design and experimental studies. Specifically, a detailed evaluation of all relevant FY'74 and FY'75 NSF and ERDA grants and contracts, including Phase 0 studies, will provide an assessment of the current state of the art of solar heating and cooling components and

subsystem technology. Additional studies will be initiated to provide an adequate information base for systems performance analysis and some conceptual desgins. Also, a review of other programs sponsored by industry, NBS, ASHRAE, HUD and NASA will be undertaken.

The NASA-Lewis is currently conducting real sun and simulated testing of solar collectors in addition to analytical and experimental model systems analysis for solar heating and cooling. These efforts will all provide input to a systems analysis program. The systems analysis will be a continuing effort whose ultimate goal is to provide an accurate computer simulation of system performance. It will serve to define preliminary component and subsystem specifications as well as provide a base of comparison for all subsystem and system breadboard testing.

Early cost assessment guidelines will be provided by a contract effort to define the cost envelope for mass produced collectors of different materials of construction and manufacturing techniques. A parallel contract study will look at the manufacturing technology of advanced collector designs aimed at high-temperature operation for advanced cooling components.

Second year efforts will provide increased emphasis on component technology advancements, with ongoing cost assessments. Additional technology will include contracted studies and experimentation on advanced collectors, coatings, materials of construction, energy storage systems of variable temperatures and different media, solar heat pump systems, control concepts and designs, and advanced solar cooling designs. Component and subsystem technology advancements will be initiated with contracts for detail designs and fabrication of solar heating components that show promise of high performance and reasonable cost based on model systems analysis studies. Sufficient exercise of model systems software will provide the basis for initial component and subsystem definition and preliminary design studies.

Current plans for the component/subsystem test phase will use at least two locations around the country as sites for real sun testing, and Lewis for real sun and simulated testing. Site selection and preparation, and preliminary test plans will be initiated in FY'76. Specific collector types

will be tested at selected geographic/climate locations based on system analysis output. Real sun tests will be run inexpensively in a specially designed portable collector test unit which is "plugged in" at each location.

Program emphasis in the third year will shift to an intensive component technology fabrication and test phase, in parallel with increased design activity on heating, cooling, and combined heating and cooling systems. Final design of solar heating or cooling systems will be completed by the second quarter of FY'78. These designs will undergo a thorough cost assessment prior to fabrication. Initial systems test efforts, particularly facility buildup will also be started.

By the end of the fourth year, fabrication of solar heating and solar cooling systems will be complete and preliminary testing will be underway. Combined solar heating and cooling systems designs and cost assessments will be complete and fabrication well underway. Final cost assessment studies of all systems will be reported. This report will include actual fabrication costs of those systems to be tested as well as projected mass production costs.

The final year of the program will be devoted primarily to breadboard system testing and evaluation in addition to ongoing component development and testing. Preliminary solar heating and/or cooling performance results will be reported early in the period and combined solar heating and cooling preliminary performance results will follow six months later. Final testing and initial evaluations will begin in the last quarter. All systems test data will be compared with model system analysis results to provide a performance basic for technical programmatic recommendations. In addition to further component technology advancement studies, efforts to establish key manufacturing technology will be carried out during the latter two years of the project.

Facilities: Basic facility needs have already been identified and any other special requirements will be determined as the test plans for new components and subsystems are further defined.

The basic facility needs that have been identified fall into two categories: component and subsystem test facilities, and final system test

facilities. Current plans and schedules indicate that the Lewis outdoor and indoor solar collector facilities are adequate for testing collectors. The Lewis model systems test facility will also be used for subsystem and system dynamics testing. Two new facilities will be required for testing advanced solar cooling subsystem components, and for testing advanced energy storage devices. Additional outdoor testing of solar heating, solar cooling and combined solar heating and cooling collectors will also be carried out at other geographical locations. Additional outdoor systems tests are planned for at least two other locations on the basis of system type and climatic region.

Utilization of ERDA-Funded Projects: The ERDA's past, present, and future advanced research and technology activities in solar heating and cooling can provide substantial input to the component and subsystem technology efforts of this project. A determination of which specific contracts/grants may be directly relevant to the NASA effort will be made on a continuing basis. The NASA-Lewis will monitor these selected ERDA grants and contracts for a period of approximately 3 to 6 months following initial ERDA award. At the end of that time, a determination of the applicability, relevancy, and timeliness of the activity to the project will be made by NASA-Lewis. If the work is not of direct, significant impact to specific project needs, additional monitoring will not be carried out, except for occasional reviews to assist ERDA evaluations. However, if there is sufficient direct relationship to the NASA technology activities, then project management and funding in subsequent years may be shifted to the Project Office.

Present Status

The NASA-Lewis has been engaged in solar energy research since 1972. A summary of these research activities is shown in figure 3; additional details are available in references 4 to 20. Present activities in support of the heating and cooling project include: (1) a project office has been established, (2) expanded or new test rigs for both air-cooled and water-cooled solar collectors, energy storage devices, and solar air

conditioners are in design, and (3) initial monitoring visits have been made to selected ERDA contractors whose projects appear relevant to the NASA-Lewis project.

Planned Activities

Figure 4 shows a summary of planned activities. The majority of these activities will be contracted to the industry. The numbers in the right-hand column of figure 4 indicate the number of contracts anticipated. Multiple contracting will be used in an effort to foster and involve as much industry participation as possible in this project.

The present Lewis analytical and experimental programs in collectors, solar selective coatings, and test operation of the model system will continue and expand. The solar simulator is now being modified to provide the capability for testing air-cooled collectors. We will continue the test of industry-developed collectors, air or water cooled, at no cost to the supplier. New test rigs now in design stages will be able to test industry-developed solar heat pumps, air conditioners, and energy storage devices. Also, components developed on ERDA or Lewis contracts will be brought to Lewis for performance testing. The model system, air conditioning, and energy storage test facilities are sized for the equivalent of about 3 tons of refrigeration cooling. The NASA Langley solar test bed will be filled with several different collector types for long-term tests in a real system.

Concluding Remarks

A solar heating and cooling project has been established at the NASA-Lewis Research Center to provide the enabling technology to the ERDA for the National solar heating and cooling program.

The NASA-Lewis project is intended to produce a significant advance beyond the technology of present state-of-the-art systems. This activity will involve utilization of information generated by the entire ERDA solar program as well as initiation by NASA of additional technology advancement efforts. This technology effort will be coordinated with, and be responsive

to, any other NASA activities undertaken for ERDA in solar heating and cooling, such as systems development or demonstrations. To this end, the NASA-Lewis project office will not only be responsible to ERDA for achieving the goals of the project, but will also be responsible for assuring maximum utilization within NASA of the output of this work. In addition to providing technology support for near-term demonstrations, the project will provide a technology base for small business and new industry growth in the 1978-1985 period, and for demonstrations beyond 1980 using Ger ...ion II systems.

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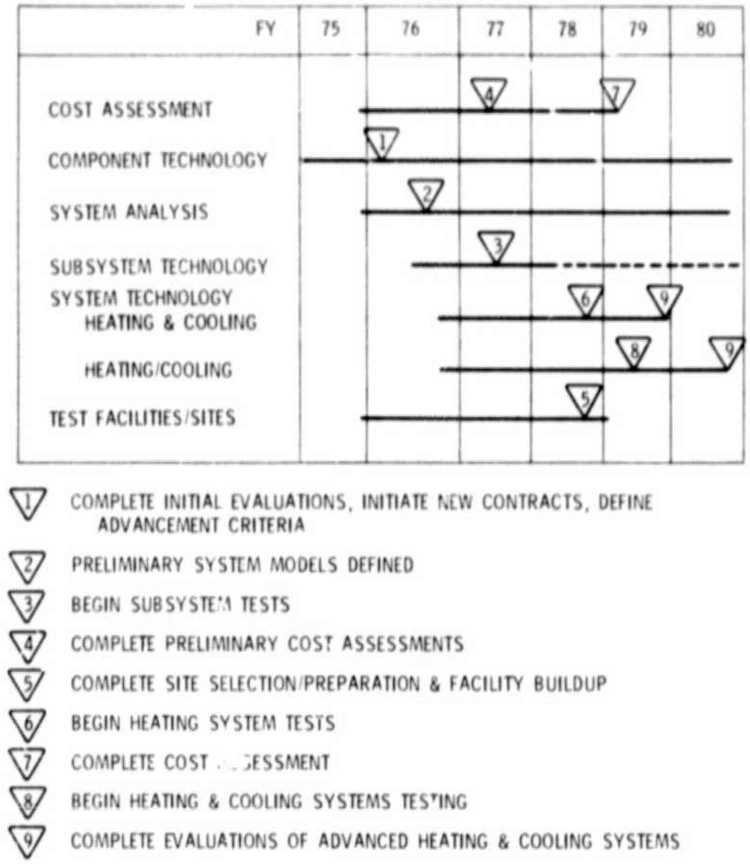

Figure 1. - Project schedule and milestones.

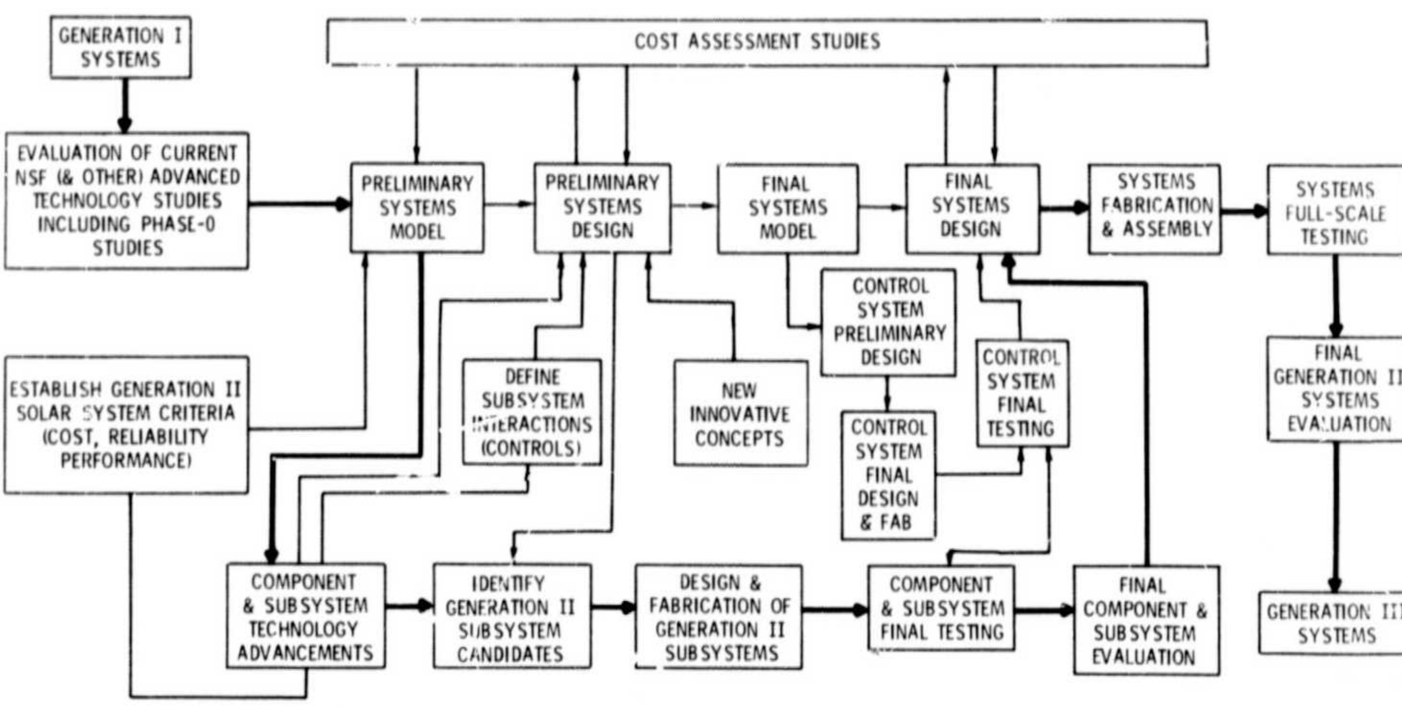

Figure 2. - Solar heating and cooling technology project flow diagram.

INDOOR SIMULATOR TEST FACILITY FOR WATER-COOLED COLLECTORS, WHICH HAS TO DATE TESTED OVER 20 DIFFERENT COLLECTORS.

TWO OUTDOOR COLLECTOR TEST STANDS WHICH NOW HAVE 10 DIFFERENT COLLECTORS UNDER TEST WITH OVER 3000 HOURS TOTAL TEST TIME.

A LABORATORY SCALE EXPERIMENTAL MOCKUP OF A COMPLETE SOLAR ENERGY SYSTEM.

OVER 100 COATING PROPERTY TESTS COMPLETED.

LANGLEY BUILDING SOLAR TEST BED BEING INSTALLED FOR FIRST OPERATION IN JANUARY 1976.

Figure 3. - Previous activities.

	CONTRACTS
COST ASSESSMENT STUDIES	
COST ENVELOPE FOR MASS-PRODUCED COLLECTORS	1
COMPONENT TECHNOLOGY	
EVALUATION OF EXTERNAL PROJECTS	1
NEW COATINGS & MATERIALS	3
DESIGN & BUILD ADVANCED COLLECTORS	3
DESIGN & BUILD ADVANCED ENERGY STORAGE DEVICES	2
DESIGN & BUILD ADVANCED HEAT PUMPS	2
DESIGN & BUILD ADVANCED AIR CONDITIONERS	3
ANALYSIS & DESIGN OF CONTROLS	2
UNSOLICITED PROPOSALS	?
ADVANCED SUBSYSTEMS AND SYSTEMS TECHNOLOGY	
TEST RIGS, BUILDUP, MODIFICATIONS, & SUPPORT	--
DESIGN STUDIES OF ADVANCED SOLAR HEATING TEST SYSTEMS	3
DESIGN STUDIES OF ADVANCED SOLAR HEATING & COOLING TEST SYSTEMS	4
TOTAL	26

Figure 4. - Planned activities.